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SOCIETY
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KYOTO

ANNOUNCEMENT

JOURNAL OF GEOMAGNETISM AND GEOELECTRICITY

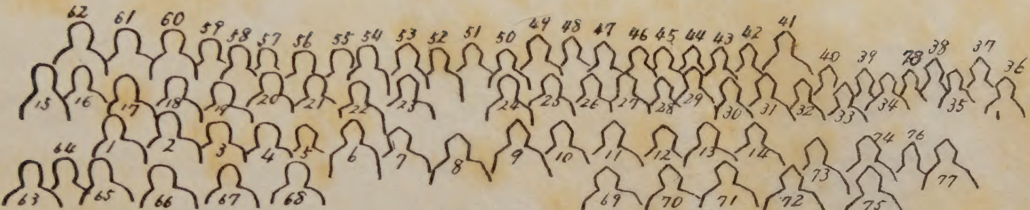
More than 120 original papers were read during the last two semiannual meetings of the Japanese Society of Terrestrial Magnetism and Electricity. Notwithstanding the many difficulties now prevailing in this country, the demand for publication is strong. The editorial committee has decided to issue the Journal of Geomagnetism and Geoelectricity on a minimum plan; to publish twice this year, on account of the limitation of pages and a high page charge for the writers. But, expecting the improvement of conditions in the near future, the committee intends to make the Journal a quarterly publication, free from any kind of restriction and page charge for manuscripts from private individuals in and outside of Japan.

The fields of interest of this Journal are as follows:

Terrestrial Magnetism	Aurora and Night Sky
Atmospheric Electricity	The Ozone Layer
The Ionosphere	Physical States of the Upper Atmorphere
Radio Wave Propagation	Solar Phenomena Relating to the Above Subjects
Cosmic Rays	
Electricity within the Earth	And Other Similar Topics

The text should be written in English, German or French. The price is provisionally set as 150 yen per copy subject to change. We hope to exchange this Journal with periodical publications of any kind in the field of natural science.

M. HASEGAWA



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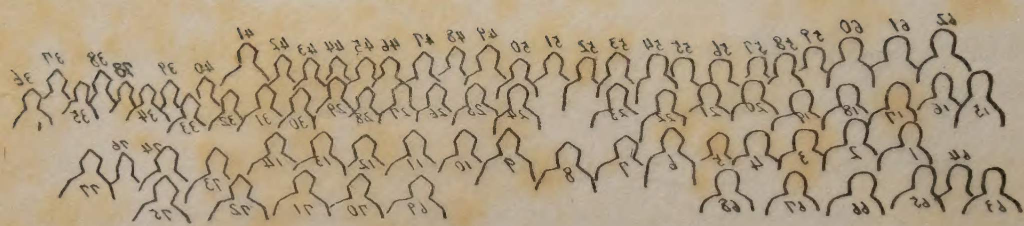

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The Third General Meeting at Kakioka Magnetic Observatory.

June 5 ~ 7, 1948.

A GREETING*

By Prof. A. TANAKADATE.

(Author's free translation)

Mr. President! Dear Colleagues!

I would like first of all to offer a word of congratulation to all the members for making this General Meeting such a brilliant success. Then, Dr. RIKITAKE, and Dr. YONEZAWA, I wish to tender you my hearty greetings for your deserving acceptance of this society's prize, associated with my humble name. These small books, "Toki wa Uturu", recently published, I present to each of you, not as an additional prize, but simply as a souvenir of this happy day. If you will read it at your leisure, I shall be more than grateful.

Now, you ask me to say a few words and I am happy to do so. I have just recalled an event that happened when PRINCE SAIONZI was Minister of Education concurrent with Minister of Foreign Affairs. He once invited the teaching staff of the Science College of Tokyo Imperial University to an informal dinner, and unreservedly discussed all sorts of subjects. The host indulged in his views on cosmopolitan principles and naturalism so extravagantly, that Prof. YAMAGAWA seriously warned him against his atitude. Curving the question, the host said: "Generally speaking, such things as decorations should not be confined to bureaucrats and soldiers, but should be widely distributed among the common populace; for instance, wouldn't it be appropriate to decorate such an actor (considered to be low class at the time) as DANZYURO who has so much improved the modern drama?" Whereupon, came an opportune voice: "Shouldn't scientists come befors actors?" The question then turned, "To whom?", and it was decided to decorate Lord KELVIN of England (HELMHOLTZ had already gone), and I was commissioned to ascertain Lord KEIVIN's intention about accepting the honor, while I was on route to attend the International Geodetic Congress in 1898.

When I came home with the satisfactory report of my mission, the cabinet had changed and AOKI was the Minister of Foreign Affairs. He hesitated in agreeing with the decision saying: "It wouldn't be proper to honor a Britisher before a German." To smooth over this unexpected hitch, I went to SAIONZI, who said: "AOKI's German —— KATO's English ——, Ha ha ha ha! I'll think of someone fit for the parley."

The matter, however, was not settled so soon; meanwhile the cabinet

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* At the first awarding ceremony of this society's prize on 26 Oct., 1948, the honourable member Dr. A. Tanakadate, 93 years old, made this speech and encouraged the audience, his successors in geomagnetic and electric researches in Japan.

changed again, and AOKI was accidentally succeeded by KATO, who re-examined the question and agreed to the decision. And I had to draft the testimonial of the merit of KELVIN's works and hand it over to the official bureau where it was scrupulously examined, and returned requiring it to be re-written including both merits and labor (Kô and Rô). I argued that the question of labor had nothing to do with this matter, but the officials insisted that such logic did not hold in the bureaucratic world, however plausible it might be elsewhere. So I had to fill up the document with some assorted scripts to pass it through.

When I told this story to my old senior, Dr. TYUTOKU ISIGURO, he told me about a much more awkward experience that he had. He once took with him a decoration for VIRCHOW of Germany, which his political enemy BISMARK prevented him from accepting. VIRCHOW himself was quite satisfied with the thought of the honor attributed to him unmindful of the material symbol. ISIGURO, had to take it home and he had stupendous trouble over red-tapism in returning it to the issuing bureau.

Happy to say, all such things are now thoroughly gone and I doubly rejoice that today's ceremony has been conducted so harmoniously without a shade of senseless officialism.

Now, my dear Colleagues, you are all occupied in various kinds of research and some are directing your juniors at the sametime, so I will just relate a little of my old experiences whether it be of any use or not.

It is well known that great discoveries and inventions do not always come from great men. Nor are geniuses devoid of failures and misconcepts. MAXWELL in his remarks about FARADAY's "Experimental Researches in Electricity" says, that its great value lies in the writing down of all his failures as well as all his successes, which arouses sympathy among its readers and inspires them to follow a similar path.

When ROENTGEN was said to have found the wave length of the X ray, I asked him personally how he found it. He said simply: "It was an optische Täuschung (illusion)." and taking out a photograph showed me what seemed to be a line produced by diffraction which disappeared when the hand was brought near it. (Think of its spectrum, now.) Then taking me to lunch with his family, asked me what I lectured about in Tôkyô. I told him that I lectured on MAXWELL's Electricity and Magnetism. Then he said: "I read that book too; only, his vector potential is very hard to understand." I told him that there are some who persistently object or dislike that term, but whatever name be it called, the idea is very useful in expressing the electro-magnetic relation.

TAIT, the co-author of "Natural Philosophy", once told me that when he talked with KELVIN about telephone transmission through a submarine cable, KELVIN said: "If such a thing happens, I will eat my hat!"

Such incidental outburst of flashing thought was not unusual in intimate talks of this open-hearted genuine thinker. Most likely his thoughts were imersed in his indefatigable hobby, the Atlantic cable.

Think of the first telegraph receiver of GAUSS and WEBER still preserved in Göttingen! It consists of a large heavy magnet suspended by a piece of thread

and surrounded by a few turns of insulated wire, through which if a current is sent the magnet will move sluggishly with the speed of, say, a classical Noh player who announces: "Now, let me go along in a slow slow tempo!"
The signaling through the Atlantic cable (born 2 years after my own birth) was predicted by highest authorities of the time to be of similar behaviours, because of its great electro-static capacity. The overcoming of this difficulty by the invention of the siphon recorder was looked upon with much pride.

To such a system of mechanical contrivance whatever elaborate refinement were persisted in, the realization of signalling hundreds and thousands per second of sound elements of the human speech would be as impracticale as swallowing a hat. The problem had to be attacked from an entirely different side, the electro-magnetic induction which had been long waiting there since FARADAY's discovery in 1931.

It is rather surprising that KELVIN, while revealing the oscillatory discharge of electricity 33 years ahead of HERTZ's experiment, did not turn his thoughts there. But the moment HEAVISIDE hit the point, he rushed to calculate the skin effect of oscillatory current with his ber and bei functions in 1888, the year I was first introduced to Sir Wm. THOMSON, later the Lord KELVIN.

In his presidential address to the Institution of Electrical Engieers on January 10, 1889, KELVIN recapitulates the histoical development of the electric science and its applications since the days of FARADAY's research and his uninterrupted attempts to elucidate the ultimate structure of electro-magnetism, his dynamic analogy of the motion of viscous fluids, of elastic solids, and of his gyrostatic ether, in every case coming to face "inscrutable difficulties." he concluded by saying;

> "We shall learn to look on things in a different way —— when that which is now a difficulty will be the only common-sense and intelligible way of looking at the subject."

These difficulties of 60 years ago have been and are still being pursued by succeeding generations with continuously improved means, theoritical and experimental in the West and the East.

It is consoling to reflect that we the surrendered living under the present critical circumstances, are yet permitted to participate in the noble pursuits of human knowledge, thanks to the generous and compromising administration of the Occupation Army.

Considering what our predecessors have accomplished under similar or even worse circumstances, we are all sensible to the rightful and pleasant duty of making the best of our efforts, notwithstanding the impendent struggle through the material want and mental strain, to afford any contribution however insignificant, toward the respective subjects to which every one of us is duly devoted.

The Electric Charge neutralized by the Lightning Discharge.

By H. HATAKEYAMA.

The electricity of the thunderstorm was observed by various facilities during the summer, from 1940 to 1944, in the neighbourhood of Maebashi, Gumma Prefecture, where records the top occurrences of thunderstorm in Japan. The report (1) of the observations in the summer, 1940 and 1941, was already published. In the present paper the author intends to report the electric charge neutralized by the lightning discharge and the distance of the consecutive discharge in the thundercloud.

Observational materials used in this study is the photographic records of the antenna-earth current. The small antenna, 10 m in length and 3 m in height, was connected to the one electrode of the galvanometer (sensitivity: $3 \times 10^{-8} A/mm$), and the other electrode was connected to the earth. When a lightning discharge occurs the electricity, positive or negative, induced on the antenna is released and flows to the earth suddenly through the galvanometer. The coil of the galvanometer makes a ballistic movement, and the maximum swing of it indicates the electric quantity flowed through it. That is proportional to the sudden change of the atmospheric electric field near the earth's surface due to the lightning discharge.

The observation was made at five places simultaneously, those were situated at intervals of several to ten kilometers each other. In 1942 the places were chosen as Maebashi, Shibukawa, Minowa, Takasaki and Fujimi, and in 1943 Takasaki was removed to Tamamura and Fujimi to Oogo. In 1944 the places were the same as in the former year. Those places are shown in Fig. 1.

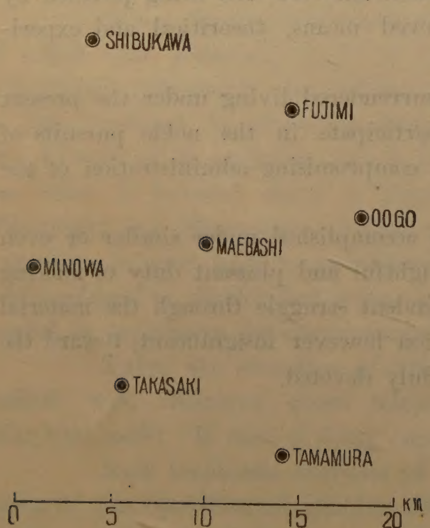

Fig. 1.

By the simultaneous observations of the sudden change of the electric field due to the lightning discharge in the summer, 1940 and 1941, it was found that the sudden change was small and occurred on both sides of the zero line when the discharge was far away from the observing places, and the sudden change was large and only on positive side when the discharge was in the neighbourhood. Thus we may conclude that almost all the discharge is vertical in the cloud. And from the relation between the distance from

(1) Journ. Met. Soc. Jap. Vol. 25, p. 41. 1947.

the discharge and the amount of sudden change of the electric field, it was concluded that the most lightning discharge occurred between the lower negative charge distributed over the circular cylinder of 2 km radius, extending from 4 km to 8 km from the earth's surface, and the upper positive charge over the cylinder extending from 8 km to 12 km. By projecting the respective discharges on the map it was found that the discharging spots shifted from the original region to another drawing the zig-zag course as if in the random walking. The dimension of the region where the lightning discharge occurs has the diameter of about ten kilometers. The distance of consecutive discharge ranges from one to five kilometer, and its average is 3.5 km.

In the observation in three summers from 1942 to 1944, we investigated twenty four thunderstorms. We took 171 simultaneous observations of sudden changes of the electric field at three places and 543 simultaneous observations at two places. The general tendency of the results of the analysis was nearly the same as in the Summer of 1940 and 1941. The following results were obtained by the detailed analysis of the observational materials.

(1) The electric charge neutralized by a lightning discharge is larger and generally more than 100 coulombs and seldom reaches 300-400 coulombs when the thunderstorm is developing as shown in Fig. 2 with full lines.

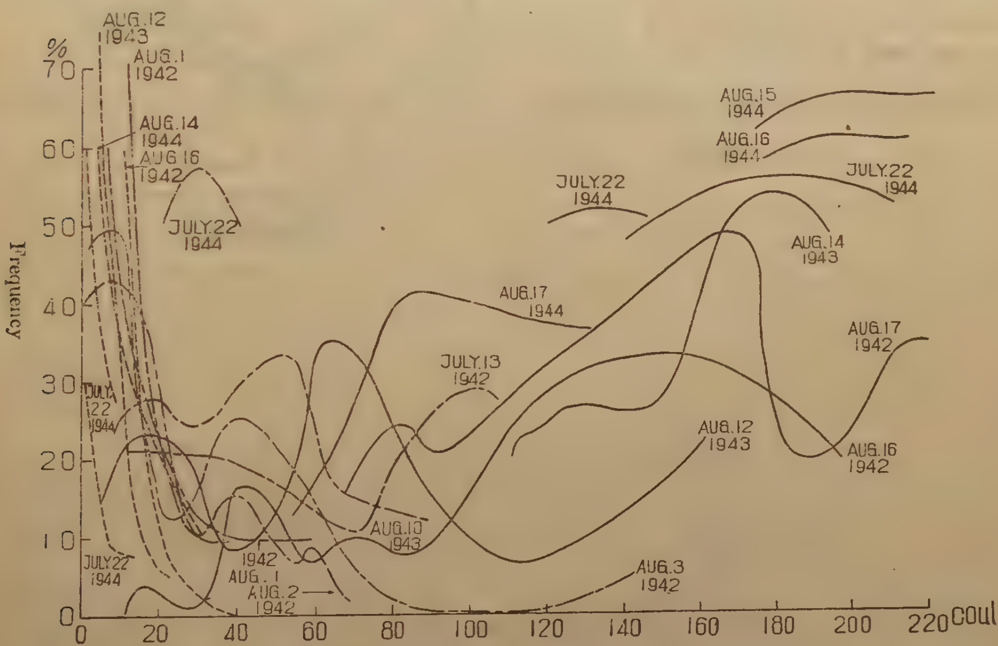

Fig. 2. The electric charge neutralized by a lightning discharge

(2) The electric charge neutralized is smaller and generally less than 40～60 coulombs, and most numerous in the region less than 10 coulombs when the thunderstorm is decaying as shown in the figure with broken lines.

(3) The electric charge neutralized is medium when the thundercloud is moving and stationary in the electrical activity as shown in the figure with chain lines. And also it is perceived that the electric charge neutralized is greater in the

front side of the thundercloud, and smaller in the rear side of it.

(4) These facts may be due to the ending of the generation of electrified water drops and to the increase of the electrical conductivity of the air in the clouds.

(5) The distance between the discharging spots is larger in the developing stage of the thunderstorm and smaller in the decaying stage. And the distance becomes larger as the electric charge neutralized by a lightning discharge becomes greater. The distance is about 1 km when the electric charge in 10-20 coulombs, 2-3 km when the charge is 100 coulombs, and more than 4 km when the charge is 300 coulombs. The relation is shown graphically in Fig. 3.

(6) The rather large negative change of the electric field somewhat frequently occurs in eighteen thunderstorms out of twenty four storms examined. These negative changes occur in the decaying stage of the thunderstorm. This may perhaps be due to the horizontal lightning discharge.

Sept. 1948

The Central Meteorological Observatory,
Tokyo, Japan.

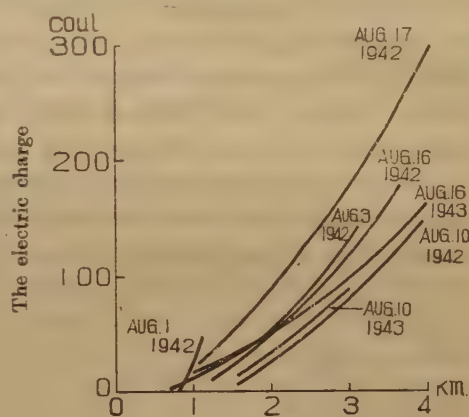

Fig. 3.
The distance between the discharging spots.

Southward Shifting of the Auroral Zone Accompanying the Growth of a Magnetic Storm

By Takesi NAGATA

Geophysical Institute, Tokyo University

(Read May 5, 1948, Received Feb. 1, 1949)

It is well known that the polar distance of the auroral zone is generally larger for greater magnetic storms. [1] Moreover, the fact has recently been noticed [2] that the auroral zone gradually shifts southward as the corresponding storm grows intense. Here in this paper an example of the above mentioned southward shift of the auroral zone will be quantitatively discussed.

The hourly change in the world-wide distribution of the disturbance geomagnetic field in the case of a magnetic storm of May 1, 1933 GMT, was examined in detail.

The distance θ of the central line of the auroral zone in Europe and America as measured from the geomagnetic axis pole was determined from the distribution of component of the disturbance geomagnetic field, and its hourly values are shown in Fig. 1. In the figure, the change in the absolute value of the horizontal force vector of disturbance at Thule (geomagnetic latitude $\varphi_m=88°$) is also shown as it may indicate change in the S_D parallel current in the polar cap.

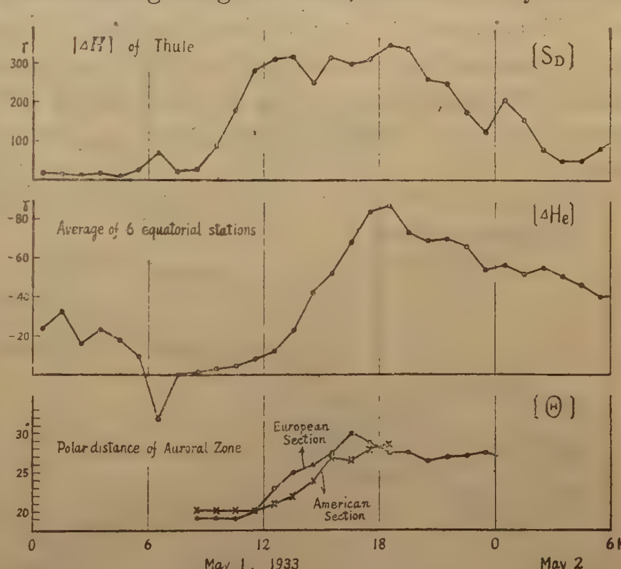

Fig. 1. Hourly changes in the intensity of the polar parallel current (top), the equatorial value of the zonal field (middle), and the geomagnetic polar distance of the auroral zone (bottom).

As shown in the figure, the auroral zone began to shift southward from about 12^h, and after reaching 61° in the geomagnetic latitude at about 19^h, it gradually went up northward. The same conclusion was obtained also, basing on the vertical component of disturbance force according to the following criterion. If ΔX_m and ΔZ denote the geomagnetic north-and downward-components respectively, a station, for which $\Delta X \cdot \Delta Z < 0$, is defined to be situated on the northside of the auroral zone, while one for which $\Delta X \cdot \Delta Z > 0$, on the southside.

Now, for the purpose of representing the equatorial value of the storm-time variation D_{st}, the mean value of $\triangle X_m$ at the following six equatorial, station was taken: Alibag, Antipolo, Honolulu, Huancayo, San Juan, and Eliasbethville. This mean value, which will be written as $\triangle H_e$, is believed to be free from the effect of S_D-field. The hourly variation in the equatorial value of D_{st} thus determined is shown also in Fig 1.

The variations in θ, $\triangle H_e$ and the S_D parallel current being compared with each other in Fig 1, it will be noted that θ changed almost in proportion to the intensity of the main phase of D_{st}-field, while the S_D parallel current began to increase sensibly earlier than the southward shifting of the auroral zone. The above-mentioned fact will be more definitely understood in Fig 2, where the mean value of θ in Europe and America are plotted against the magnitude of $-\triangle H_e$.

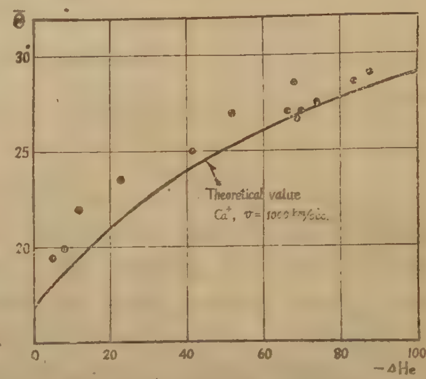

Fig. 2. Relation between the geomagnetic polar distance of the auroral zone and the equatorial value of D_{st}-field.

The southward shward shifting of the auroral zone may be the result of the deviation of the corpuscular stream caused by the magnetic field of the equatorial ring current, which is the source of the main phase of D_{st}-field. In this connection, an extended from of the C. Störmer's solution for the said problem [3] was applied in order to estimate in detail the deviation of Ca^+ stream having the velocity of 1000 km/sec, the result being shown by the full line in Fig 2. Notwithstanding the well known difficulty involved in the Störmer's theory [4], the calculated curve seems to agree rather well with the observed results.

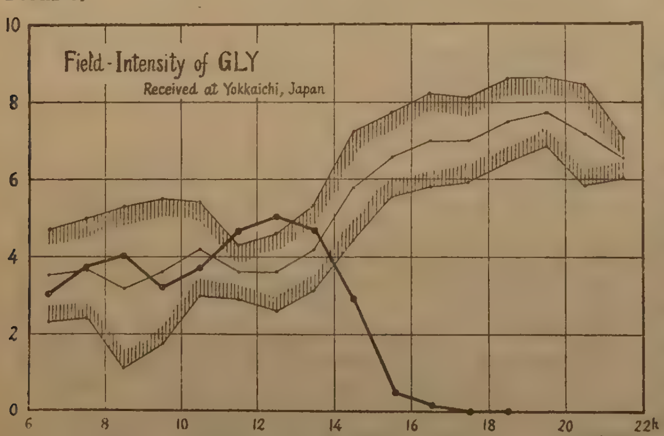

Fig 3. Anomalous Change in the field intensity of GLY on May 1. 1933 (thick line)
The thin line shows the average normal value, while the shadow band indicates the width of the mean individual fluctuation.

Thus, the mode of development of a magnetic storm will be interpreted as follows. First, the charged corpuscular stream ionizes the polar region, especially forming the auroral zone at 17°∼20° in θ. The velocity of the corpuscles in the stream, however, remains almost constant, about 1000∼2000 km/sec. Then, secondly according as the equatorial current ring is formed and becomes intense, the magnetic field due to it will shift the corpuscular stream, resulting the movement of the auroral zone.

On the other hand, the anomalous variation in the field intensity of GLY (Dorchester, England, f = 11420MC) radio wave, received at Yokkaichi, Japan, on May 1, 1933, is shown in Fig 3, together with the average variation during the neighbouring five days for the sake of comparison. The first apex point of the path of propagation of radio waves from Dorchester to Yokkaichi is situated at $\varphi_m = 63°$, in the middle Scandinavia.

Comparing Fig 3 with Fig 1, we may say that the field intensity of GLY began to decrease just after the apex point at $\varphi_m = 63°$ became occupied in the auroral zone owing to its southward shift, and the communication was kept in bad conditions as long as the apex point remained in the auroral zone. This fact may suggest that F_2 layer itself is disturbed above all in the auroral zone, resulting in the increase of the absorption of radio waves as well as of their penetration due to the anomalous decrease in the critical frequency.

The detailed result of analysis of the mode of development of this magnetic storm and related phenomena will be reported in the Geophysical Notes of Tokyo University in a near future. In conclusion, the writer wishes to express his sincers thanks to Prof. M. Hasegawa for his kindness in putting the necessary valuable geomagnetic data at the writer's disposal.

References.

[1] S. Chapman and J. Bartels : "Geomagnetism", Vol.1, pp 475.
L. Harang : Terr. Mag. 51 (1946), 353.

[2] T. Nagata : Proc. Ionosphere Res. Spec. Comm. N. R. C. Japan Vol. 1, (1948), 74.

[3] C. Störmer : C. R. 151 (1910), 736.
Z. S. Astrophys., 1 (1930), 237 : 3 (1931), 31, 227 : 4 (1932), 290.

[4] A.Schuster : P. R. S. 85 (1911), 44.
S. Chapman : P. R. S. 95 (1919), 61.

A New Type Magnetometer. (The G. S. B. Type Magnetometer)

By Ietsune TSUBOKAWA

Geographical Survey Bureau, Ministry of Construction

(Read. Oct. 28, 1948; Received Feb. 1, 1949)

A new type electromagnetic magnetometer for the purpose of field survey was designed and constructed at our institute of the Geographical Survey Bureau. By means of this instrument the geomagnetic force vector can be determined with the sufficient accuracy, i. e., with the error less than 0.1′ in declination and inclination and 1γ in horizontal intensity, while the time need for a set of observations of three components is about six minutes or less.

The instrument consists of a Helmhortz coil of 80mm in its mean radius and a small rotating coil as the detector. The Helmhortz coil is set on the theodolite so that its axis is perpendicular to both of the horizontal and vertical axes of the latter, while the rotating coil is set perpendicular to the axis of the theodolite. With the aid of an alternating current amplifier with a magic eye (6G5), the e. m. f. generated into the rotating coil by the geomagnetic force can be detected with the sufficient sensitivity. Declination and dip are simultaneously measured by adjusting successively the horizontal and vertical directions of the axis of the rotating coil so that the output of the amplifier becomes null.

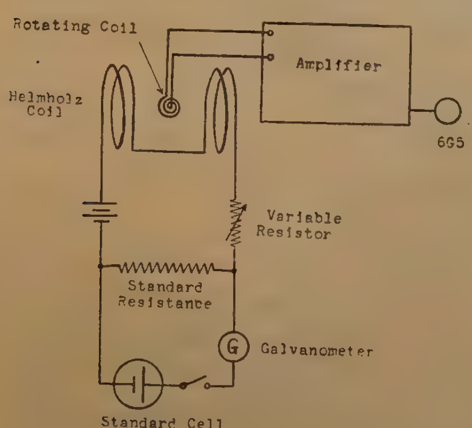

Fig. 1
Electric circuit of the system for measuring the horizontal component of geomagnetic field.

The principle of measuring the horizontal intensity is shown in Fig. 1. Here, the constant magnetic field produced by the Helmhortz coil which is regulated by a current standard meter is superposed on the geomagnetic field. The direction of the resultant magnetic force is measured with the aid of the detector. Then, the horizontal intensity is given by

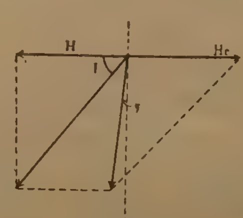

Fig. 2

$$H = H_c \frac{\cos\varphi \cos I}{\cos(\varphi + I)}$$

where H_c, I and φ denote respectively the magnetic force of the Helmhortzcoil, dip, and the angle between the vertical line and the axis of the rotating coil.

In this instrument, the standard resistance is prepared so that φ may not exceed 4°, in order to minimize the errors due to the setting condition. In actual measurement of each component, four readings are taken corresponding to the symmetric positions in the instrument, in order to eliminate the systematic errors owing to various parts. Finally, the constant of the Helmhortz coil was determined by comparison with the standard value.

This magnetometer was practically used for the magnetic survey on Shikoku during three months in 1948, and it was proved that this instrument is sufficiently useful and quite safe for the field works.

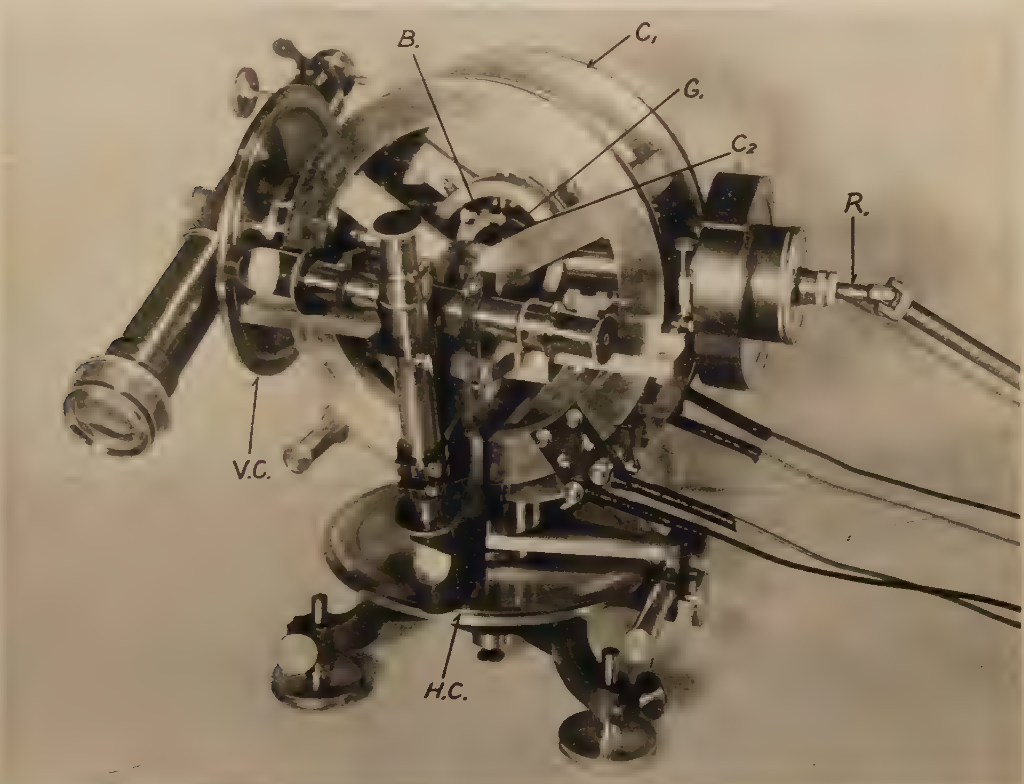

Fig. 3. The magnetic theodolite in the G S B type magnetometer
C_1 : Helmholtz-Coil
C^2 : Rotating Coil
B : Collector
G : Bebel Gear
R : Universal Joint to rotate the Rotating Coil
H. C : Horizontal Circle
V. C : Vertical Circle

Fig. 4. G S B magnetometer in the field work.
Left to right; magnetic theodolite, magic-eye, standard-cell and resistance, galvanometer and amplifier.

Characteristics of Geomagnetic Diurnal Variation at KAKIOKA.

by S. IMAMITI.

The diurnal inequality observed at KAKIOKA during 21 years 1925 to 1945 was analysed in the usual way in a series

$$c_1 \sin (t + \delta_1) + c_2 \sin (2t + \delta_2) + \cdots\cdots\cdots$$

where t is time counted from midnight (J. C. S. T.), one hour being taken as equivalent to 15°. Thus c_1, c_2, c_3, and c_4 denote the amplitude, δ_1, δ_2, δ_3, and δ_4 the phase angles of the terms whose periods are respectively 24, 12, 8, and 6 hours.

The subject of such an analysis is to give the characteristics of diurnal variation at KAKIOKA, providing the influences of different geomagnetic conditions of days, that of seasonal difference and sunspot period, and to know average condition at the same station. As KAKIOKA is situated in the central part of Japan, the characteristics at KAKIOKA may be considered as the general figure of geomagnetic diurnal variation in Japan.

Calculations were made on horizontal intensity (H), vertical intensity (V) and declination (D). Geomagnetic conditions were divided into three classes, namely, calm days, ordinary days (including calm days) and disturbed days. Winter includes November to February, summer, May to August, and equinox, the remaining monthes. Years of 1927, 1928, 1929, 1936, 1937 and 1938 were adopted as sunspot maxmum period and 1932, 1933, 1934, 1943, 1944 and 1945 as the years of minimum.

The result of calculation shows that c_1, c_2, and c_3 of H, V and D increase as we pass from sunspot minimum through 21 years to sunspot maximum, but c_4 of H does not varies in the above order and, in V, it increases in the reversed order.

According to magnetic conditions, c_1 of declination and vertical intensity increase as we pass from calm days through ordinary days to disturbed days, but c_1 of horizontal intensity changes irregularly. c_2, c_3 and c_4 generally vary in the same order as c_1, exceptionally in vertical intensity and in the case of sunspot minimum years for horizontal intensity.

c_1 and c_2 are larger in summer and smaller in winter, but c_2 of horizontal intensity shows rather irregular change. On the other hand, c_3 of every element is largest in equinox and smallest in winter, indicating frequent occurrence of such variations of nearly 8 hours period in spring and autumn. c_4 changes irregularly in declination, but that of horizontal and vertical intensity show highest value in equinox and lowest in summer.

In the following table, the four terms of calm days as well as sunspot periods are given, and the complete table will be inserted in the report of the KAKIOKA Magnetic Observatory.

Calm days	Declination			Horizontal Intensity			Vertical Intensity		
season.	SPmin.	21 years.	SPmax.	SPmin.	21 years.	SPmax.	SPmin.	21 years.	SPmax.
c_1 Year	1.00	1.12	1.26	2.27	3.77	5.30	4.41	5.71	7.10
c_1 Winter	0.28	0.42	0.58	0.60	1.15	2.77	3.11	4.18	5.27
c_1 Equinox	1.00	1.17	1.34	2.61	4.61	6.25	4.40	5.86	7.54
c_1 Summer	1.60	1.77	1.87	4.09	5.86	7.53	6.10	6.90	8.44
c_2 Year	0.97	1.12	1.33	4.18	5.59	6.99	3.53	4.12	5.02
c_2 Winter	0.52	0.59	0.75	3.30	3.90	5.22	3.43	3.61	4.26
c_2 Equinox	0.97	1.12	1.29	5.33	7.07	8.34	3.43	4.23	5.21
c_2 Summer	1.46	1.69	1.99	5.51	7.01	8.72	4.06	4.65	5.58
c_3 Year	0.66	0.74	0.87	2.96	3.77	4.66	3.03	3.32	3.72
c_3 Winter	0.55	0.61	0.71	2.52	2.89	3.60	3.05	3.05	3.26
c_3 Equinox	0.77	0.89	1.01	3.87	5.01	5.99	3.39	3.86	4.25
c_3 Summer	0.71	0.79	0.93	3.77	4.19	4.92	3.39	3.52	3.99
c_4 Year	0.22	0.24	0.25	0.90	1.12	1.41	1.18	1.24	1.27
c_4 Winter	0.31	0.37	0.38	1.00	1.29	1.82	1.40	1.44	1.57
c_4 Equinox	0.31	0.36	0.40	1.37	1.84	2.19	1.63	1.82	1.89
c_4 Summer	0.14	0.14	0.15	0.96	0.92	1.22	1.09	0.99	0.86

Declination is given in minute and horizontal and vertical intensity in γ.

The Wave Form of Atmospherics in Day Time.

By Atsushi KIMPARA

Nagoya University.

This paper gives an account of an investigation of the wave form of atmospherics received mainly during the day time in summer, and discusses the interpretation of the records obtained.

Recent studies of atmospherics, largely concerned with wave forms, may be devided in two groups: the one has been made by Lutkin (1939) in England, and the other by Laby (1940) in Australia as well as by Schonland (1940) in Africa. The former considers that the whole of the daylight wave form arises from oscillations and multiple discharges in the parent lightning channel. The latters suggest that the structure of the high frequency portion of atmospherics, which appears as a damped wave train of gradually increasing wave length, arises from multiple ionospheric reflexions of a single pulse of short duration.

The wave form of atmospherics should be studied from the mechanism of general electric discharges in the atmosphere in addition to their propagation condition, such as of the amplitude ratio of each wave component due to distance, the masking effect of nearer electric discharges, daily and seasonal variations of the absorption and the reflexion-coefficient of E-layer, and etc.

It is here shown that the forms taken by all daylight atmospherics in summer arise directly from some kinds of electric discharges in the atmosphere. The observations were made in Kanto-District of Japan from 1940 to 1944 at the Iwatsuki Receiving Station. The cathode-ray direction finders were installed here and at Kakioka Magnetic Observatory situated at a distance of 56 km. They were employed to find the origin of atmospherics observed.

The equipment for observing wave forms consisted of cathode-ray oscillographs with associated wide band amplifiers & antenna system, combined with appropriate accessories such as cathode-ray beam suppression unit, cathode-ray beam maintenance unit, compensation unit of supply main interferrence, recording cameras, testing equipment and etc. The amplifier has a very flat frequency response from 25c/s to 300kc/s and a very linear voltage amplification characteristic between 0.004 and 0.4 volts input, delivering a gain of 54db. In order to record fiqures on oscilloscorpes two movie cameras and a rotating cylinder camera were placed in front of oscilloscopes, aperture ratio of lens being f : 0.85, 0.85 &1.5 respectively. We adoped electrical and mechanical sweeps, the former having a scanning speed of 100m/s for fine structures of wave forms and the latter having film speeds of 7.2 m/s for wave forms and 4 cm/s for direction finding.

During the period of observations 8,500 wave forms were recorded among which the following types were remarked and discussed.

(1) Atmospherics radiated from lightning discharge between clouds & earth.

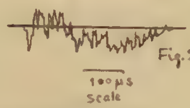

Fig. 2.

A direct stroke between clouds & earth is preceded by a leader stroke which radiates irregular waves of higher frequencies than the main stroke, but the amplitude is much smaller than that of the main stroke. (Fig. 2).

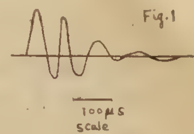

Fig. 1.

The main stroke follows the leader stroke & appears on the oscilloscorpe as a damped oscillation, being completely attenuated in several cycles (Fig. 1). When the discharge occur near the station, static component can be observed as well as superposed high frequency components.

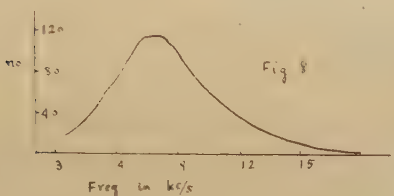

Fig. 8.

In Fig. 8, the statistical frequency distribution of the first half wave, occurring in the damped wave form originated from the main stroke, is plotted, which indicate that the initial high frequency component occurs most often at about 7.5 kc/s. The frequency in any particular damped wave train is further seen to decrease as wave attenuates. These periods coincide, fairly well with those of stripes of lightning discharge figures on Boy's camera.

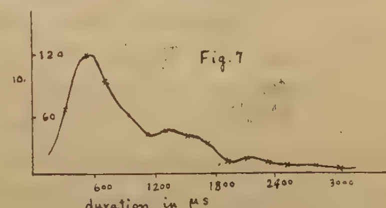

Fig. 7.

In Fig. 7, a curve is plotted showing the distribution of the durations of damped wave form trains. Those are seen to vary from 300 to 1800 μs, with a most frequent value of about 600 μs.

In Fig. 4 & 5, several consecutive wave trains of the similar wave forms are indicated with intervals from 1 to 10 ms. separated. These are radiated from multiple stroke in the same channel of discharge between clouds & earth.

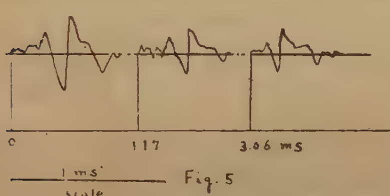

Fig. 5.

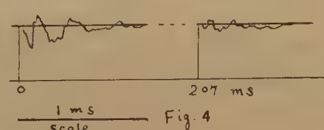

Fig. 4.

(2) Atmospherics radiated from lightning discharge between & within clouds.

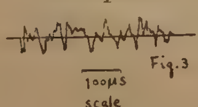

Fig. 3.

In the case of discharge from one cloud to another with intervaning clouds involved, a series of closely separated, damped oscillations appears on the oscilloscope as successive discharges occur from cloud to cloud, which seems to occur often in summer & people are apt to take it for long lightning discharge (Fig. 3).

Within cumulo-nimbus numerous small discharges may occur continuously, giving rise to considerable atmospherics whose wave form is similar to that of leader stroke (Fig. 2).

(3) Atmospherics due to multiple reflexions from E-layer.

These wave forms were discovered by Schonland at winter night in Johanesburg, Union of South Africa. We found them also at night in autum as shown in Fig. 6.

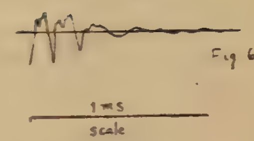

Fig. 6.

(1) T. H. Laby : Proc. Roy. Soc. A, vol. 174 p. 145 1940.
(2) B. F. J. Schonland : Proc. Roy. Soc. A, vol. 176 p. 180 1940.
(3) F. E. Lutkin : Proc. Roy. Soc. A, vol. 171 p. 285 1939.
(4) A. Kimpara : J. Nippon Elec. Eng. June 1943.

On the Semi-Diurnal Lunar Tide (M_2) in Region F.

By Sadami MATSUSHITA.

Geophysical Institute, Kyoto University.

1. Statistical Treatment.

From January, 1947, to February, 1948, the values (Zm) of the real height of maximum ionization by every hour in Region F at Kokubunji (139° 29.3′ E, 35° 42.4′ N) were examined, and the full 29 days, after the epoch of the new or the full moon in each month were analyzed. The phase and the amplitude of the tide were calculated dividing them into three groups: 1. December Solstice, 2. June Solstice, 3. Equinoxes. The mean values of the phase and the amplitude of the tide are derived from the application of the harmonic dial method.

On the other hand, for the same purpose, the 369 days from January 6, 1947 to January 10, 1948, were analyzed using the following four methods:

1. Using of the hourly values for the full 369 days.
2. Obtaining the difference between the hourly values and the median values of each month, for the purpose of avoiding the influence of the solar tide.
3. Application of the hourly values at night (April to September, from 2100 to 0200 hrs. Other months, from 2200 to 0300 hrs.), for eliminating errors caused in the day time.
4. Using of the difference between the hourly values at night and the median values.

		A		B	
		Region F		Lower Atmosphere	
		Amplitude	Phase Angle	Amplitude	Phase Angle
Dec. Solstice		3.1 Km	223°	24 μb	39°
Jnne Solstice		3.5	272	31	79
Equinoxes		3.2	272	24	82
Mean Values		3.0	252	25	65
Mean Values of One Year (369-Days)	1	2.7	212		
	2	3.8	213		
	3	3.7	285		
	4	3.8	263		

Table. 1.

All of these results are tabulated in Table 1 A. The curve obtained from the mean values of one year is shown in Fig. 1. The phase angle and the amplitude of M_2 tide in the lower atmosphere near the ground at about 35° N, as determined by Chapman (1) for the barometric pressure is shown in Table 1 B. It is indicated that the amplitude of December Solstice and

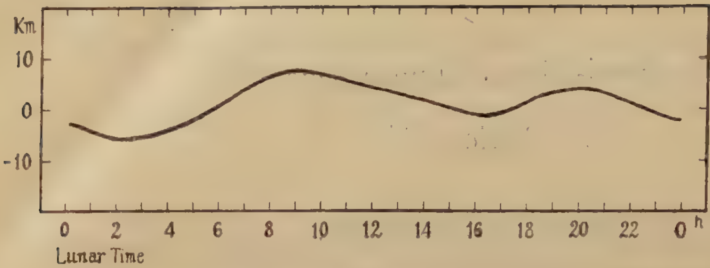

Fig. 1. M_2 tide in Region F at Kokubunji.
(mean values of one year, using the method of 2)

Equinoxes in both A and B is smaller than that of June Solstice. The phase angle of June Solstice and Equinoxes in both A and B is larger than that of December Solstice, and the phase difference between A and B is nearly 180°.

Though the data examined are only for the period of 14 months, the results are interesting as compared to Chapman's L field of terrestrial magnetism.

2. *Theoretical Treatment.*

More nitrogen molecules and oxygen atoms than electrons and ions are discovered in the ionosphere. Therefore, on the whole, the ionospheric atmosphere seems like a rare gas electrically neutral. When this atmosphere oscillates mechanically, the electrons and charged ions will act to obstruct the motion, for they are under the constraint of electric and magnetic forces. But, as they are few in number than neutral molecules and atoms, their force of obstruction is very little on the whole. Accordingly, the variations of Zm may be influenced chiefly by the large number of neutral molecules and atoms.

Thus, in the first approximation, the hydrodynamics may be applied to the discussion of the motion in Region F. If the atmosphere in Region F is an autobarotropic one surrounding the non-rotating spherical earth, it will have the proper oscillation of 12 hours period (2) using Haurwitz' method (3). In the case of the rotating earth, it is also proved (2) that the abovementioned region has the same proper oscillation by following Taylor (4) and Hough's equation (5). By the gravitational effect of the moon on the atmosphere in this way, it is understandable why M_2 tide appears in Region F so clearly.

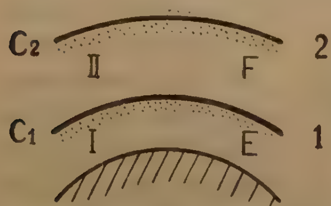

Fig. 2.

The amplitude and the phase of M_2 tide in the region may be discussed by using Haurwitz' equation (6). In the two layers of I and II, as shown in Fig. 2, the ratio of the amplitude C_1 at the boundary surface 1, to C_2 at the free surface 2, is as follows:

$$C_1/C_2 = 1 - RT_1^I\ n(n+1) / A^2\ B^2$$

A indicates the radius of the earth, B the number of

(1) O. R. Wulf and S. B. Nicholson. Terr. Magn. 175 – 182 (1947)
(2) S. Matsushita. Collective Report of Co-operative Observations of Ionosphere Research Committee. (Kyodo Kansoku Kekka Torimatome Hokokushu.) Edition 4. (National Research Council of Japan.) Oct. 1948.
(3) B. Haurwitz. Beitr. z. Geophys. 51, 195–233 (1937)
(4) G. I. Taylor. Proc. Roy. Soc. Lond., A. 156 (1936)
(5) S. S. Hough. Phil. Trans. A. 189 (1897)
(6) B. Haurwitz. Met. ZS. 54, 69–70 (1937)

oscillation, n the degree of the spherical function, R the gas constant number of unit mass, and T the temperature of the boundary surface 1 in the I–layer.

When Region E and Region F are in the position as shown in Fig. 2, the ratio of the amplitude C_f of M_2 tide in Region F, to the amplitude C_e in Region E, is given by the value, 0.4∼0.1, according to the abovementioned equation, where R is 4.14×10^6, n is 2, and $T_1^!$ is 200° T∼320° T. Therefore, when the amplitude of M_2 tide in Region F is 3.6 Km. and the scale height of Region F and E is 36 Km. and 12 Km. respectively, then the amplitude of M_2 tide in Region E is expected to be 0.48 Km.∼0.12 Km..

For the purpose of examining the ratio of the amplitude between Region E or F and the lower atmosphere near the ground, we divided the atmosphere into six layers according to the temperature-height curve, as shown in Fig. 3.

Thus we have:

$$C_a/C_f = C_e/C_f \cdot C_d/C_e \cdot C_c/C_d \cdot C_b/C_c \cdot C_a/C_b \cdot K$$
$$= -0.005K \sim -0.001K$$

$$C_a/C_e = C_d/C_e \cdot C_c/C_d \cdot C_b/C_c \cdot C_a/C_b \cdot K = -0.01K$$

where, K is a constant value applied for correction due to division into many layers. For the temperature of each layer, we employed the value as shown in Fig. 3. For R, 4.14×10^6 is used for C_e/C_f and C_d/C_e, 3.50×10^6 is used for C_c/C_d, and 2.87×10^6 is used for C_b/C_c and C_a/C_b. The minus sign indicates that the phase difference between Region F and also E and the lower atmosphere is 180°, and it corresponds to the foregoing statistical results. When the amplitude of M_2 tide in Region F is 3.6 Km., and when the pressure variation in the lower atmosphere is 25 μb, K is 0.05∼0.25, using the abovementioned scale height. Therefore, the quantity of the relative air pressure oscillation of Region F and E is 4,000 and 1,200 respectively times than that measured on the ground level. (In the case of S_2 tide (7), K is about 0.4; the relative pressure oscillation of Region F and E is 800 and 250 respectively times than that on the ground level. It corresponds to Pekeris' results (7).)

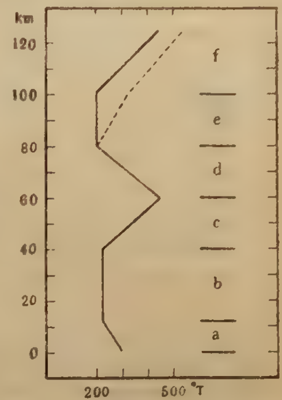

Fig. 3. Diagram of the division of the upper atmosphere into six layers.

In conclusion, from both the statistical and theoretical results, Region F seems to possess M_2 tide with the amplitude of 3∼4 Km., and a phase difference of 180° as compared to the atmosphere in the lower level.

The thanks of the author are due to Prof. Dr. M. Hasegawa and Dr. T. Nagata for many helpful suggestions during the course of the research.

(Oct. 25, 1948)

Supplementary:

Most recently, the lunar variations in Region F at many stations were also analyzed dy Martyn (8). The results of his experiments and the writer's are

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(7) S. Matsushita. (to be published in the near future.)
C. L. Pekeris. Proc. Roy. Soc. Lond., A. 158, 650–671 (1937)

illustrated in Fig. 4. It shows coincidence and a fairly good agreement with one another on the subject of the certainty of the existence of M_2 tide in Region F.

If the lateral distribution of the amplitude of the M_2 tide is given as $4\,\mathrm{Sin}^2\theta$ Km. (θ is colatitude), and the phase is 252° as obtained from the above-mentioned results in Table 1, at all places, then the lunar tidal vertical rise and fall of isobaric surface in Region F is

$$4\,\mathrm{Sin}^2\theta\ \mathrm{Sin}\ (2t+252°)\quad \mathrm{Km.}$$

Therefore, the relative pressure oscillation in the region is

$$0.0924\ P_2^2\ \mathrm{Sin}\ (2t+252°)$$

using Appleton's estimation (9). P_2^2 is Schmidt's spherical function.

In the case of the non-rotating earth, the velocity distribution due to such an oscillation is obtained easily, by following Bartels' equations (10). (Maximum velocity is of order 30 m/s.) The velocity potential having velocities like these is

$$\psi_2^2 = 1.31\times10^{12}\ P_2^2\ \mathrm{Sin}\ (2t+162°)$$

When the electric conductivity K is constant, the magnetic potential V_3^2 as caused by this velocity potenial, applying Chapman's dynamo theory (11), is as follows:

$$V_3^2 = 1.63\times10^{12}\ K\ P_3^2\ \mathrm{Cos}(2t+252°)$$

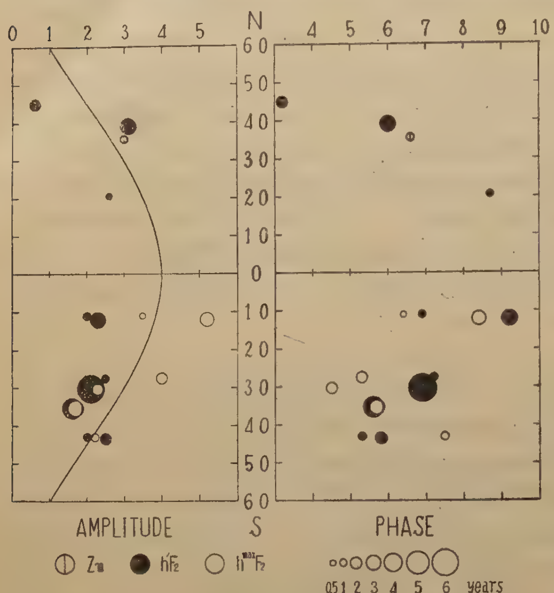

Fig. 4. The amplitude (in Km.) and the phase (in lunar hours after transit at which maximum occurs) for the semi-diurnal harmonics in the lunar variation of $h'F_2$, $h^{max}F_2$ and Zm (Kokubunji) for various locations. The relative weights are indicated by the radius of the circle, which is proportional to the number of lunar months of hourly data examined.
Curve: $4\,\mathrm{Sin}^2\theta$ Km. (θ is colatitude)
(The phase at Huancayo, near the magnetic equator, are anomalous, being markedly dependent on solar time. –from Martyn.)

On the other hand, the lunar magnetic potential of the external part of the L field is given by van Bemmelen (12), who handled the magnetic data statistically. It is

$$V_3^2 = 2.55\times10^3\ P_3^2\ \mathrm{Cos}\ (2t+258°)$$

for the mean values of Mean Solstice and Equinox.

Comparing these two equations of V_3^2, the phase coincidence is clear. Also K is determined by the coefficients of the equations as follows:

$$K=1.6\times10^{-9}\qquad \mathrm{e.\ m.\ u.}$$

As the integral conductivity in Region F is of order 10^{-7} to 10^{-8} e. m.

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(8) D. F. Martyn. Nature. No. 413, 35 (1949)
(9) E. V. Appleton and K. Weekes. Proc. Roy. Soc. Lond., A. 171, 171–187 (1939)
$p=p_0\,e^{-h/H}$ where H is the local scale height for the ionized atmospheric component; if h/H is small relative to unity,
$p=p_0\,(1-h/H)$ or $dp/p=(p-p_0)/p_0 = -h/H$
(10) J. Bartels. Handbuch der Experimental Physik. XXV, 1 Teil, 163–210 (1928)
(11) (12) S. Chapman and J. Bartels. Geomagnetism. Vol. 2. (1940)

u., M_2 tide in Region F may be sufficient to make the L field, even if the velocity, due to the foregoing oscillation, is prevented by friction or other effects. Accordingly, the "L-layer" wherein L is produced is perhaps found in Region F. (Because of the great difference existing between low and high latitudes of the phase, the oscillation in Region E is not favorable for the L field.)

N. B. In this treatise, 'Region F' means the atmosphere of F_2 Layer chiefly.

On the Distribution of Electricity in Thunderclouds

By Yuichi TAMURA

By means of the rotating collector devised by Prof. M. Hasegawa (1940), which faithfully follows the rapid changes of electric field, the electric field at the ground due to thunderclouds has been studied. Observations were done at Kyoto and at Beppu.

On the average, when lightning flashes are at small distances (less than 7 km. from observing station), the sign of net effect of a sudden field-change produced by a discharge is positive (at least 90% of cases); when lightning flashes are at great distances (more than 15 Km.) the relative frequency of negative and positive net effect is 3 to 1.

The average electric moment of a discharge of negative and positive polarity is 100 and 60 Coulomb-Kilometers respectively.

Field recovery curves which suggest the progression of the regeneration of charge in a cloud after a discharge, are divided into various types as shown in Fig. 1.

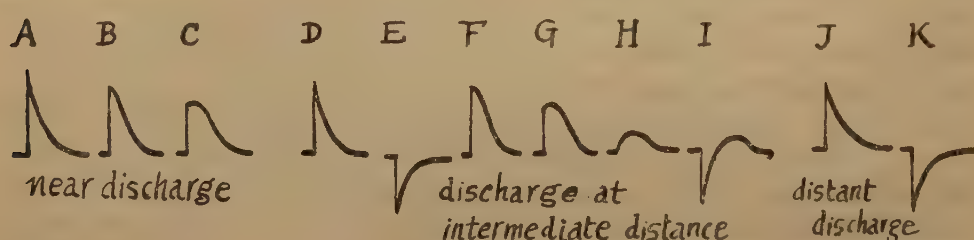


Fig. 1. The Types of field change.

In the types A, D, E, J and K, the rate of recovery is a maximum immediately after the discharge and thereafter continually decreases. In the types B ad F, there is a smaller initial rate of recovery which later increases and finally dies away to small values. In the types C and G, the field soon after the completion of a discharge varies in the same direction as the net effect, reaches a maximum value and finally decreases. In the type H, no appreciable net effect is seen, but the variation of field after a discharge is similar to the type C or G. In the type I, the rate of recovery is a maximum immediately after the discharge and decreases gradually to zero, and, thereafter, changes its sign (consequently the field varies across the predischarge value and reaches to a maximum and then decreases).

Field-changes of all types seen here except the type H and I were discussed by wilson (1921) and later, more in detail, by Wormell (1939), though in their cases the types A, D, E, J and K were the most familiar ones, while the types B, C, F and G were treated as not common types.

In the case of thunderclouds in Japan, it is striking fact that the types B, C, F and G are common as well as A, D, E, J and K type, and furthermore, the types H and I also occure frequently.

By simultaneous observations, at three points, of field-changes produced by the same lightning discharges and, on the other hand, by statistical studies on relative frequencies of each type of field-change, the transition of types of field-change along distance from a lightning flash could be deduced as follows.

(a) A ———— D — E ———— K

(b) $\begin{cases} \text{A ———— F — G — H — I ———— K} \\ \text{A — B — C ———— H — I ———— K} \end{cases}$

(c) A ———— D ———— J

These three series of transition lead us to picture the polarity of thundercloud and probable modes of discharge as shown in Fig. 2. In this figure, we treat the charges as points in the same vertical line, and their heights above the ground are 2H, 3H, 4H and 5H respectively. Further, the assumption is made that the quantity of discharge is the same in each case, represented by symbol Q_0.

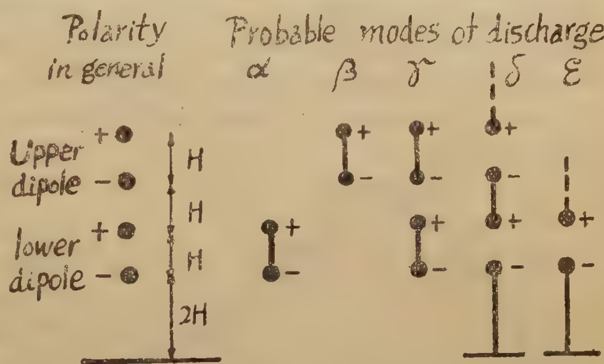


Fig. 2. Polarities and modes of discharge.
———— lightning discharge
- - - - - - gradual discharge

The signs of field-change and the moment of lightning discharge, on an assumption that H=1 Km., and $Q_0=20$ Coulombs, are given in the table.

Modes of discharge		α	β	γ	δ	ε
Sign of field change at	near	+	+	+	+	+
	distant	—	—	—	+	+
Moment of discharge	Coul. -Km.	40	40	80	-120	-80

Table.

Assuming that the regeneration of charge after a lightning discharge, is expressed by an equation of the general form of

$$Q=Q_0\,(1-e^{-\lambda t}), \quad \cdots\cdots\cdots (1)$$

the transition of type of field-change is interpreted as follows.

After the α– or β–discharge, electric field F at the point of horizontal distance L from frash is expressed by

$$F_\alpha=2Q_0\,(1-e^{-\lambda_1 t})\left[\frac{3H}{(9H^2+L^2)^{3/2}}-\frac{2H}{(4H^2+L^2)^{3/2}}\right] \cdots\cdots\cdots (2)$$

or

$$F_\beta=2Q_0\,(1-e^{-\lambda_2 t})\left[\frac{5H}{(25H^2+L^2)^{3/2}}-\frac{4H}{(16H^2+L^2)^{3/2}}\right]. \cdots\cdots\cdots (3)$$

Either the equation (2) or (3) is an explantion of transition (a). After the γ–discharge in which the upper and the lower dipole discharges simultaneously, the effect is expressed by

$$F_\gamma=F_\alpha+F_\beta\,, \qquad \lambda_1>\lambda_2 \cdots\cdots\cdots (4)$$

(4) is an explanation of the transition (b), though the physical meaning of $\lambda_1 > \lambda_2$ is not clear at the present stage of my investigation. In the case of $\delta-$ and $\varepsilon-$discharge, some complications of circumstance will be added. Gradual discharge of the uppermost charge to the outer space of a cloud will begin considerably affecting the field, after the lightning discharge is completed; the variation of space charge below a cloud will modify a recovery curve. Though a sufficient explanation is not yet obtained, it is probable that the transition (c) is intimately connected to $\delta-$ and $\varepsilon-$discharges.

When a thundercloud is at a distance, the positve field-changes are (mostly) due to the $\delta-$ and $\varepsilon-$discharges, the former being an evidence of both the lower and the upper dipoles, and the latter of the lower dipole in action. The negative fiield-changes are due to the $\alpha-$, $\beta-$ and $\gamma-$ discharges; the $\alpha-$ or $\beta-$discharge being an evidence of the lower or the upper dipole respectively in action, and the $\gamma-$ discharge an evidence of both dipoles in action. From this standpoint of view, frequency of occurence of sudden field-changes of each sign during the distant storms were examined.

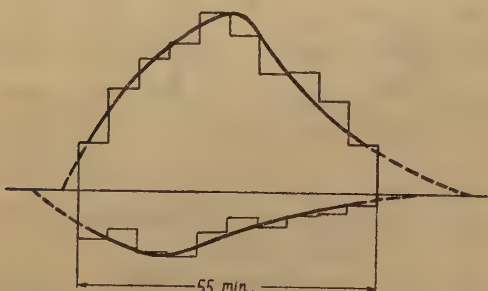


Fig. 3. The mean frequency of sudden fiield changes during distant thunderstorms (Upper–negative sign, lewer–positive sign), and the electrical activity curves.

Fig. 3 is one of the results of such examination. In this, nineteen distant storms of durations between 30 min. and 90 min. were considered. The duration of each storm was devided into equal ten periods, and numbers of positive and negative sudden changes appearing in each period were counted. The mean values of these numbers are graphically represented. The curves obtained by smoothing the observed values may be called the "electrical activity curve of a thundercloud"; the upper is the activity curve concerning the $\alpha-$, $\beta-$ and $\gamma-$discharges, and the lower that concerning the $\delta-$ and $\varepsilon-$discharges. It must be noted that both the curves have similar forms, but the phase of the upper curve lags behined that of the lower.

This result of examination leads us to the conclusion that the activity of the upper dipole (timely) lags behined that of the lower one, which is schematically represented in Fig. 4, showing the life history of a thundercloud from the electrical point of view.

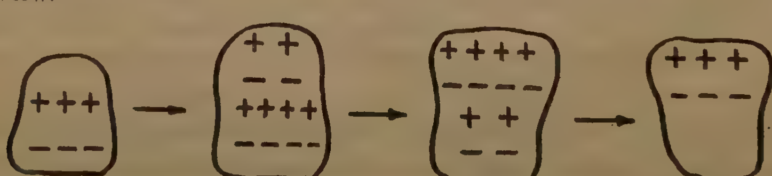


Fig. 4. C.ange of the distribution of charge in a thunderclond duri g its life.

The direct measurments interior of clouds by Simpson and Scrase (1937), Simpson and Robinson (1941) show us that there are, in general, two kinds of

separation of electricity, the one is in the water region and the other is in the ice region in a cloud. As for the Japanese thunderclouds, it is quite probable that the upper dipole is in the ice region and the lower dipole is in the water region,

References

Hasegawa 1940 Chikyubutsuri (Geophysics) 4 p.161
Simpson and Scrase 1937 Proc. Roy. Soc. A 161 p.309.
Simpson and Robinson 1941 Proc. Roy. Soc. A 177 p.281.
Wilson 1921 Phil. Trans. A 221 p.77.
Wormell 1939 Phil. Trans. A 238 p.249.

Geophysical Institute, Kyoto University. Feb. 15, 1948.

On the Fluctuation in Electron Density of the F2 Layer of the Ionosphere

by T. Yonezawa

(Electrical Communications Laboratory)

The effective recombination coefficient of electrons and positive ions in the F_2 layer of the ionosphere has already been determined in several ways. Appleton [1] obtained the values of 0.8×10^{-10} and 3×10^{-10} cm^3 sec^{-3} for daytime and night respectively, from the diurnal variation of electron density. On the other hand, Rydbeck [2] analyzed the data during the total solar eclipse on July 9, 1945, and obtained a much larger value, namely 3×10^{-9} for the daytime. The present author made a similar study [3] on the total eclipse on Feb. 5, 1943 in Hokkaidō, the result being 2.8×10^{-10} for the daytime. In view of these diverging results, we have thought out a new device of determining the recombination coefficient by analyzing the fluctuations in the elctron density of F_2 layer. This method is equally available during daytime as well as during night, but owing to statistical errors, it can yield good values only in the case that we have a long series of data.

After preliminary analysis by means of a method which is known as Takahashi-Fushimi's method [4] in Japan, we have been led to the conclusion that considerable persistency or after-effect must be present in the fluctuation in the ionizing agency itself of the F_2 layer. Therefore we have made an extention of this method to cover the case where persistency exists, and a renewed analysis has been carried out.

At first we introduce a parameter which represents the persistency or after-effect of the fluctuation x in the ionizing agency of the F_2 layer. From a similar consideration as in the case of the theory of errors we assume that x is a sum of a large number of x_i's ($i=1, 2, \cdots, 2N$), 2N being their number, and each x_i can only take the values $\frac{1}{2}\varepsilon$ and, $-\frac{1}{2}\varepsilon$, where ε is a very small positive number:

$$x=\sum_{i=1}^{2N} x_i, \qquad x_i=\pm\frac{1}{2}\varepsilon \qquad (i=1, 2, \cdots, 2N).$$

Now let P be the probability that x_i, taking the value $\frac{1}{2}\varepsilon$ or $-\frac{1}{2}\varepsilon$ at a moment, will take again the same value one unit time afterwards. The value of P is a measure of the after-effect and if $2P-1$ takes the value zero, there is no after-effect, and as it approaches from zero to unity, we have an increasing after-effect. $2P-1$ is a quantity which may appropriately be called the "after-effect coefficient".

Under these assumptions we can find out the probabilities $W(n, n\pm k)$ that x, taking the value $n\varepsilon$ at a moment, will take the values $(n\pm k)\varepsilon$, respectively, one unit time afterwards (n and k are positive integers or zero). These are found to be

$$W(n,\ n+k)=P^{2N}\sum_{i=0}^{N-n-k}\binom{N+n}{i}y^{i}\binom{N-n}{i+k}y^{i+k},$$

$$W(n,\ n-k)=P^{2N}\sum_{i=0}^{N-n}\binom{N+n}{i+k}y^{i+k}\binom{N-n}{i}y^{i},$$

where

$$y=\frac{1-P}{P}$$

Employing contour integrals on the complex plane, we can transform the above expression into the following forms:

$$W(n,\ n+k)=\frac{P}{2\pi i}\oint\frac{(1+yx^{-1})^{N+n}(1+yx)^{N-n}}{x^{k+1}}dx,$$

$$W(n,\ n-k)=\frac{P^{2N}}{2\pi i}\oint\frac{(1+yx^{-1})^{N-n}(1+yx)^{N+n}}{x^{k+1}}dx,$$

Evaluating the approximate values of these integrals by the method of steepeet descent, we obtain, to the approximation that $1/N$ is neglected beside 1, the following result:

$$W(n,\ n\pm k)=\frac{1}{\sqrt{4\pi P(1-P)N}}e^{-\frac{1}{4P(1-P)N}\{(2P-1)n-(n\pm k)\}^2}$$

If ε is small enough, we can consider x to take practically continuous values, so that, putting $n\varepsilon=x$ and $(n\pm k)\varepsilon=y$ and regarding x and y as continuous variables, the probability $W(x,\ y)\,dy$ that the value of x changes in a unit time from x to a value between y and $y+dy$ is found to be

$$W(x,\ y)\ dy=\frac{1}{\sqrt{\pi}\,\sigma}e^{-\left\{\frac{(2P-1)x-y}{\sigma}\right\}^2}dy, \qquad (1)$$

where

$$\sigma^2=4P(1-P)\ N\varepsilon^2 \qquad (2)$$

In particular, if there is nothing of after-effect, $W(x,\ y)$ must represent a normal distribution curve with respect to y, as we know from the theory of errors:

$$W(x,\ y)=\frac{1}{\sqrt{2\pi\overline{y^2}}}e^{-\frac{y^2}{2\overline{y^2}}}, \qquad (3)$$

where $\overline{y^2}$ is the average value of y^2. On the other hand, with no after-effect, we have $P=\frac{1}{2}$ in Eqs. (1) and (2), so that

$$W(x,\ y)=\frac{1}{\sqrt{\pi}\sigma}e^{-\frac{y^2}{\sigma^2}},$$

$$\sigma^2=N\varepsilon^2$$

Comparing these with Eq. (3), we get

$$N\varepsilon^2=2\overline{y^2}=2\overline{x^2} \qquad (4)$$

Using Eqs. (1), (2) and (4), we can calculate some sorts of average values. for instance, the average value of $(y-x)^2$ for a given value of $x(\overline{\Delta_x^2})$ and over all values of x and y $(\overline{\Delta^2})$ are, respectively,

$$\overline{\Delta^2}=4(1-P)\{P\overline{x^2}+(1-P)x^2\}$$

and

$$\overline{\Delta^2} = 4\,(1-P)\,\overline{x^2} \tag{5}$$

The latter can also be expressed, from its definition, in terms of the correlation coefficient between a value of x at any instant and that one unit time afterwards (r_1):

$$\overline{\Delta^2} = 2\,(1-r_1)\overline{x^2}$$

Comaring this with Eq. (5), we get

$$r_1 = 2P-1.$$

In the same way, we can show that the correlation coefficient between any two values of x which are separated by a definite time-interval t (r_t) can be expressed in terms of P as follows:

$$r_t = (2P-1)^t$$
$$= e^{-\chi t} \tag{6}$$

where, assuming that $\quad 2P-1 \geqslant 0,$

$$\chi = \log \frac{1}{2P-1} \tag{7}$$

Now the fluctuation x in the ionizing agency of the F_2 layer can not be measured directly, and it is the fluctuation in the maximum electron density of the F_2 layer that can be obtained directly from observations. Therefore we must think out some device to derive from the latter values of the parameter P which represents a characteristic of the former.

We shall denote by n_0 the part of the F_2 layer maximum electron density n which represents the average variation including diurnal and seasonal variations, and let Δn be the deviation from the average. Also we shall divide the rate of ion production q into the similar parts q_0 and Δq. Then, assuming that n_0 is rouhly constant and $\Delta n \lll n_0$, Δn is given by

$$\Delta n = \int_{-\infty}^{t} \Delta q(\tau)\, e^{-2\alpha n_0 (t-\tau)} d\tau\,, \tag{8}$$

where α is the effective recombination coefficient between electrons and positive ions. The quantity which we have hitherto called the fluctuation x in the electron density of the F_2 layer may be considered to be Δq in Eq. (8). Therefore the correlation coefficient between the values of Δq at any two times $t+\tau$ separated by a definite time-interval $|\tau|$ is by Eq. (6)

$$\frac{\overline{\Delta q(t)\,\Delta q(t+\tau)}}{\overline{\{\Delta q(t)\}^2}} = e^{-\chi|\tau|}\,, \tag{9}$$

where horizontal bars signify average values with respect to t. Let the similar correlation coefficient for Δn be denoted by $R\tau$. Then,

$$R\tau = \frac{\overline{\Delta n(t)\,\Delta n(t+\tau)}}{\overline{\{\Delta n(t)\}^2}}$$

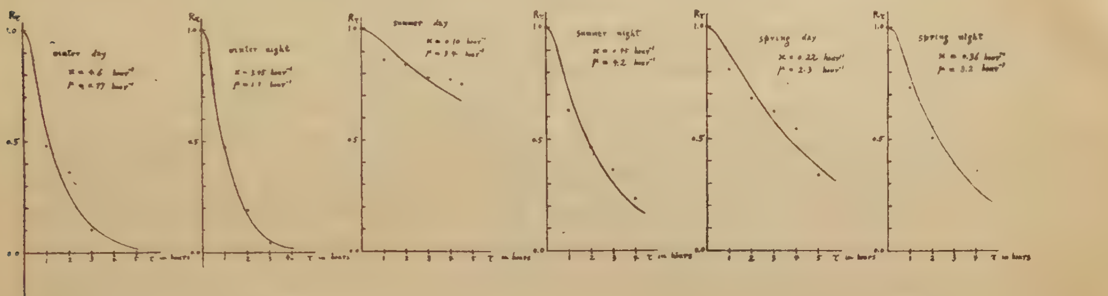
and inserting Eq. (8) in this equation and noting the relation (9) and the fact that $R\tau = 1$ for $\tau = 0$, we obtain finally

$$R\tau = \frac{\mu e^{-\chi\tau} - \chi e^{-\mu\tau}}{\mu - \chi} \tag{10}$$

where x is given by Eq. (7) and

$$\mu = 2a\, n_0 \cdot \tag{11}$$

In Eq. (10) $R\tau$ can be calculated from observational data, and if we determine the values of the parameters x and μ so that the points $(\tau, R\tau)$ obtained from observations fall as closely as possible in the neighbourhood of the curve expressed by Eq. (10), we can find out the values of the after-effect coefficient $2P-1$ and the recombination coefficient a from Eqs. (7) and (11). We have also calculated out the mean lives of the fluctuation in the ionizing ageney. The results of this task are summarized in the following table and the figure.



Solid curves are $R_\tau = \dfrac{\mu e^{-x\tau} - x e^{-\mu\tau}}{\mu - x}$
Dots indicate R_τ calculated from observational data.

On examining the practicial data, we have found out that in winter, both day and night, points obtained from observations are arranged roughly in accord with the curve (10), but in spring and summer, particularly in the latter case, this is not the case, and the values of the parameters can not so sharply be determined. The figures listed in the table may be subject to not small errors in these seasons.

From the table we see that the after-effect of the fluctuation in the ionizing agency is small in winter, large in spring and particularly large on summer day, though not very large on summer night. We have also obtained reasonable values of recombination coefficient, which seem to be a little too large on the whole. The physical meanings of these results are not clear and require further investigations.

In conclusion I wish to express my sincere thanks to Mr. T. Sobajima for asisting me in numerical work.

Table.

season	winter Dec. 10, 1946 — Jan. 10, 1947		spring Mar. 10 — Apr. 10 1947		summer Jun. 10 — Jul. 10 1947	
time of day	day 0900—1400	night 0000—0400	day 1000—1500	night 0100—0500	day 1200—1600	night 2100—0100
after-effect coefficient * 2P-I	0.010	0.032	0.80	0.70	0.91	0.64
mean life * (in hours)	1.5	1.5	0.96	6.2	21	5.0
recombination coefficient a (in $cm^3\ sec^{-1}$)	0.7×10^{-10}	11×10^{-11}	1.3×10^{-10}	$6\ 5\times10^{-00}$	4.3×10^{-10}	6.3×10^{-10}

* after-effect or mean life of the fluctuation in the ionizing agency of the F^2 layer

References

(1) E. V. Appleton, Proc. Roy. Soc. Lond. A, 162, 451 (1937).

(2) O. E. H. Rydbeck, Transactions of Chalmers University of Technology Gothenburg, Sweden, Nr. 53, 1946.

(3) This paper was presented to tne Oslo Assembly, Aug. 1948, of the International Association of Terrestrial Magnetism and Electricity. See, also, Dempa-Butsuri Kenkyûjo Danwakai-Kiji, 1, 11. (1947).

(4) K. Takahashi and K. Hushimi, Geophysical Magazine 9, 29 (1935).

SECULAR VARIATION OF EARTH-CURRENT POTENTIALS.

By T. Yoshimatsu.

(Kakioka Mag. Obs.)

Although the general physical features of so-called universal earth-currents have been much cleared in recent years, we have little informations of their local characters which must be discussed together with the actual materials on the resistivity of the earth's crust. Regarding to the other kinds of earth-current, for instance, such as those that may be primarily caused by some agencies in the interior of the earth, it is not too much to say that nothing is known at present. Considering these points and taking account of the geographical situation and geological activities of the Japan Island, some analyses and discussions about observed potentials have been made mainly from the standpoint of the locality of earth-currents. Here is described only a general feature of the secular variation of the absolute values of potentials. Before stating the subject, it may be convenient to note some elements of the equipment of the new base lines installed at the end of the year 1933, near the Kakioka Magnetic Observatory, upon which records the present paper mainly depends.

The base line arrangement is of a cross type, not a single commonpoint one, and their lengths are one and half kilometers in the east-component and one kilometer, north-south, respectively. Potential differences were continuously recorded by means of galvanometers of the sensibility of 10^{-8} Amp. per mm. and manganin series resistances of several ten thousand ohms, or more. The electrode consists of two copper plates connected to the line in parallel ; each of which has an area of one square meter and is burried vertically in fine charcoal gravels of three or four hundred kilograms at the depth of three to four meters, the horizontal distance being five meters apart. Before the installation, the underground wires, by which the electrodes are connected to the insulated aerial lines, were coated thickly with asphalt compound on their surfaces, then insulating test being done by a meggar. As far as the observation during the last two years by the method or Kohlrausli's bridge concerns, the mean effective contact-resitances of both east and north components are six hundred and two hundred ohms, respectively. Their seasonal variations are less than about fifty percents, while the series resistances in both circuits are several ten thousands ohms as said above.

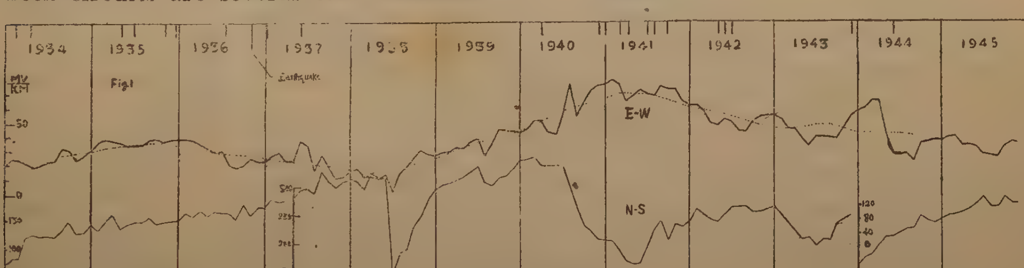


Fig. I

During the years from 1934 to 1945, the monthly means of the absolute values of potentials at Kakioka are shown in Fig. I in which positive sign is used when the current flows eastwards and southwards. In the figure the curve of the north-component is drawn in three parts because of the removal of the south-electrode in June, 1937 and that of the north-electrode in January, 1944. The extraordinary decrements in both components in July, 1938 were due to the effect of heavy rains of precipitation of 670 mm. in a week. Although the curves contain other short fluctuations and minor seasonal variations, we can notice a distinct mean long-period variaton in the east-component as shown by a dashed curve with a principal maximum in 1941 and minimum in 1938. Similar tendency in the north-component is also noticeable, but of less regularity. The annual mean derived from the data of five calm days per month also shows a similar secular variation. On the other hand, however, secular variations of ranges of both daily extreme values and diurnal variation are in good accordance with the solar and geomagnetic activities. We can not, therefore, attribute this phenomena to any such kinds of external causes as current-systems in ionospheres, but to some gradual changes of physical and chemical states of either extreme shallow layers, in which electrodes are installed, or more deep portions of the earth. At first glance variations of soil solutions are probable sources to be pointed out for the first question; as is the case, soil solutions are subsiantially controlled by the meteorological conditions and hence may be responsible for most of extraneous contact-potentials. Although we have no direct continuous observations of physical and chemical quantities of soil, such as water content, water-level in a well, resistivity in the superficial layers and so on, if these kinds of contact-potentials were responsible for the present secular variaton, it would be likely to expect more conspicuous seasonal variations than observed ones, and also it should be reasonable to expect an intimate correlation between potentials and meteorological elements, such as rain-fall, air, or earth temperature, atmospheric pressure, or its space gradient and so on. The range of the mean seasonal variation during the total years is only about twenty percent of the mean absolute value, while the extreme range of the secular variaton in the east-component is about one and half times this mean absolute value. Moreover, we have no good correlations between potentials and meteorological elements. We failed in searching for better correlation with

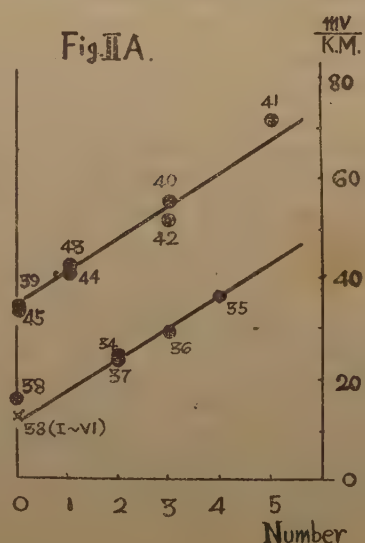


Fig. II A.

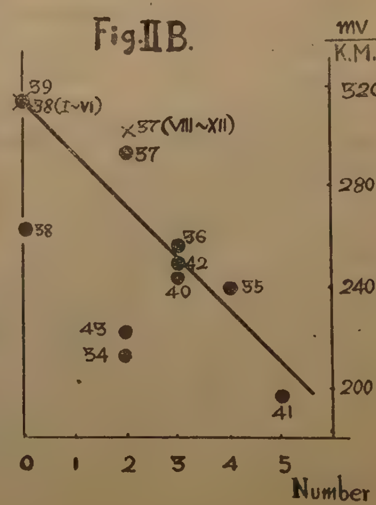


Fig. II B.

some other geophysical branches.

Lastly, however, as it is shown in Fig. Ⅱ, the writer made a lucky hit in the linear relation between potentials and number of occurrence of "conspicuous" and "rather conspicuous" deep-focus earthquakes on the belt of so-called "Transverse-Zone" of deep-focus earthquake in Japan, which runs through the middle part of the Island from the Pacific-Ocean side into the Japan Sea side. Due to the heavy rain in 1938 the absolute value of the east-component made a constant jump by which the mode of linear correlation was not entirely spoiled as shown by two parallel straight lines in Fig. Ⅱ A. By a crossed point the six months' mean from January to June in 1938 is distinguished from the annual value. For reference, in Fig. ⅡB the annual mean values of the north-component from 1934 to 1937 are added by 95.0 mv. per K.M. which is a difference between the old and new absolute values at the moment of exchanging the south-electrode, while two values in 1944 and 1945 are omitted.

This interesting fact led us to investigate the same problem about the observed potentials at Toyohara, Sagalien. During the snow-melting seasons at Toyohara, no satisfactory records were obtained on account of the abnormal variations of contact-potentials. In this case, therefore, eight months' mean was utilirized as an annual mean, excluding four months from to June. We found, however, a rather good correlation between potentials and number of occurrence of deep-focus earthquakes in the "Sôya-Zone", another deep-focus earthquake zone in Japan, which runs from the northern part of the Japan Sea into the Okhotsk Sea side, passing along the Straits of Sôya.

Thus, as far as the annual mean values are concern, it may be said that in Japan, at least, at both Kakioka and Toyohara we have a sort of local earth-current which is originated itself in the earth and changes its intensity in a similar manner with the frequency of the occurrence of deep-focus earthquakes in the vicinity of the every station which are grouped into two distinct zones "Transverse-Zone" and "Sôya-Zone".

In this paper the writer omitted many details of description, graphs and discussions about similar geomagnetic fluctuations found for which another paper will be prepared.

February, 1949

The meetings of the Society of Terrestrial Electricity and Magnetism.

The 1st General Meeting. Held at the Tôkyô University on May 12–14, 1947; 36 reports were read; 100 members assembled.

The 2nd General Meeting. Held at the Kyôto University on Oct. 17–19, 1947; 24 reports were read; 70 members assembled.

The 3rd General Meeting. Held at the Kakioka Magnetic Observatory on June 5–7, 1948; 40 reports were read; 80 members assembled.

The 4th General Meeting. Held at the Kôenji Laboratory of the C. M. O., Tôkyô, on Oct. 25–27, 1948; 50 reports were read; 150 members assembled.

The 1st and 2nd Tanakadate-prize were awarded for the following excellent works;

Mr. T. Rikitake: The electrical state of the Earth's interior.

Mr. T. Yonezawa: The research for the Ionosphere.

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